Society for Innovative Agiculture

Electricity conservation potential of household sector in Pakistan

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The consumption of electricity by the household sector has been increasing rapidly due to changing lifestyle of people for the last few years as the use of appliances in households has increased many folds. This increasing consumption has become a challenge for Pakistan to manage energy sources as per demand. The need for electricity by the household sector can be managed through studying the pattern of electricity consumption and demand-side management techniques. The current study sheds light on the behaviour of electricity consumption patterns by households having different socio-economic, demographic and appliance-related characteristics. A random sample of 133 respondents is taken from district Toba Tek Singh. A large proportion of electricity is consumed on running the household appliances used for cooking, washing, heating, cooling etc. There is need to change the behavior of people through awareness sessions and publicity regarding energy demand management and planting trees for sustainable use of electricity.
Keywords: Energy conservation, behavior, electricity management, demographic, buildings, appliance.

INTRODUCTION

Electricity is the secondary source of energy. It has become an essential part of our daily life. This is because of changing lifestyle of the current generation. Previously, consumption of electricity was little due to usage of more daylight, more physical work and eating healthy fresh food. In contrast, currently, we eat more junk food, less physical activity, sleeps and get up very late. These habits of the current generation reached the consumption of electricity at the highest rank as compared to previous years. The consumption of electricity has been increasing with every year passing. It is a great challenge for us to curtail this consumption through some demand-side management techniques.

On one side, electricity is Pakistan is generated through thermal fuels, hydro, nuclear and renewable energy sources. During 1971, thermal, hydro and nuclear share in the electricity generation process was 50.04 percent, 48.59 percent and 1.37 percent respectively. After ten years, nuclear share decreased to 45.13 percent and hydro share increased to 53.83 percent in the country. Afterward, the installation of thermal fuel plants started to fulfill the immediate need for electricity. During 1991, about 59 percent of electricity was generated from thermal fuels and about 41 percent of

electricity was generated from hydro. The share of hydro was further decreased in the succeeding years. Percentage share of thermal, hydro and nuclear sources in 2001 was 70.68 percent, 26.16 percent and 3.16 percent respectively. In 2011, a slight decrease in thermal fuel share (9.03 percent) and an increase in hydro share (14.31 percent) was observed. Renewable sources come up with a new source of electricity generation in 2014. During 2019, the share of thermal, hydro, nuclear and renewable sources was 58.42 percent, 30.86 percent, 7.98 percent and 2.33 percent respectively (various waves of Economic Survey of Pakistan). Excessive combustion of thermal fuels brought the country ranked 5th amongst the countries most affected by climate change from 1999 to 2018 (Economic Survey of Pakistan 2019-20).

On the other side, electricity is consumed by households, commercial, industry, street lights and other government departments. During 1971, the industrial sector was the largest consumer (53.54 percent) of electricity. About 18 percent electricity share is consumed by agriculture sector of the country. The remaining electricity is consumed by households (11.90 percent share), commercial sector (7.08 percent), street lights (0.58 percent) and other government departments (8.17 percent). During 1981, household consumption share increased to 25.38 percent and industrial

share decreased to 39.39 percent. A similar trend of electricity consumption was observed in 1991 when the share of households and industry was 33.82 percent and 36.27 percent respectively. A small change in consumption of other sectors was also observed but it is negligible. During 2001, households and industrial electricity consumption have 45.84 percent and 29.90 percent respectively. Further decrease in industrial share (27.50 percent) and increased household consumption (46.54 percent) was observed in 2011. During the year 2019, the consumption share of electricity by households, commercial, industry, street lights and other government departments was 49.32 percent, 7.89 percent, 25.57 percent, 8.90 percent, 0.36 percent and 7.94 percent respectively. Historically, the substitution of electricity consumption by households and industry is observed.

Electricity generation was 68,117 gigawatts per hour in 2000 and increased to 129,027 gigawatts in 2019. The growth of electricity generation is 4.70 percent per annum. Electricity demand in 2000 was 48585 gigawatts hour which has increased to 109459 gigawatts hour in 2019. The growth rate remained 6.59 percent per annum (Economic Survey of Pakistan 2019-20). There is a difference in electricity demand and electricity generation. This difference in demand and generation is due to circular debt in the supply chain mechanism (Perwez *et al.,* 2015). Resultantly, load shedding is occurred due to demand and generation gap. Incompatibility between energy demand and supply from the last two decades has been accumulative because of the costly imported oil dominance in the energy mix of Pakistan (Kamran, 2018). The economy of a country is adversely affected by load shedding as witnessed in many developing economies (Shrestha, 2010; Timilsina *et al.,* 2019; Rehman *et al.,* 2019).

The industrial sector is one of the major sectors of Pakistan's economy. Manufacturing, automobile and construction, mining and fuel industries require energy. Industry uses electricity for operating machinery, office equipment and appliances for cooling, heating and ventilation. The industrial sector contributed a significant role in the economic growth of a country. Electricity is indispensable for the industrial sector but the share of electricity consumption by the industrial sector continuously decreasing in Pakistan.

The household sector is the major consumer of electricity in Pakistan. The demand for electricity by households is derived from cooking, cooling, heating and transportation. Many household appliances are electric where electricity is required to operate these appliances like cooking, cooling, heating, information technology appliances. There is an increasing trend in electricity consumption by the household sector. The increasing electricity demand can be managed through some demand-side strategies. There is a cushion for conserving household electricity demand. Electricity can be saved by turn off the lights, switch off and unplug appliances etc (Olsen & Chen, 2003). Likewise, every rational consumer can save money from electricity bills through changing behavior in electricity use (Yoo & Kwak, 2009).

The current study carries an important contribution to the literature of Pakistan. Firstly, the household sector consumes
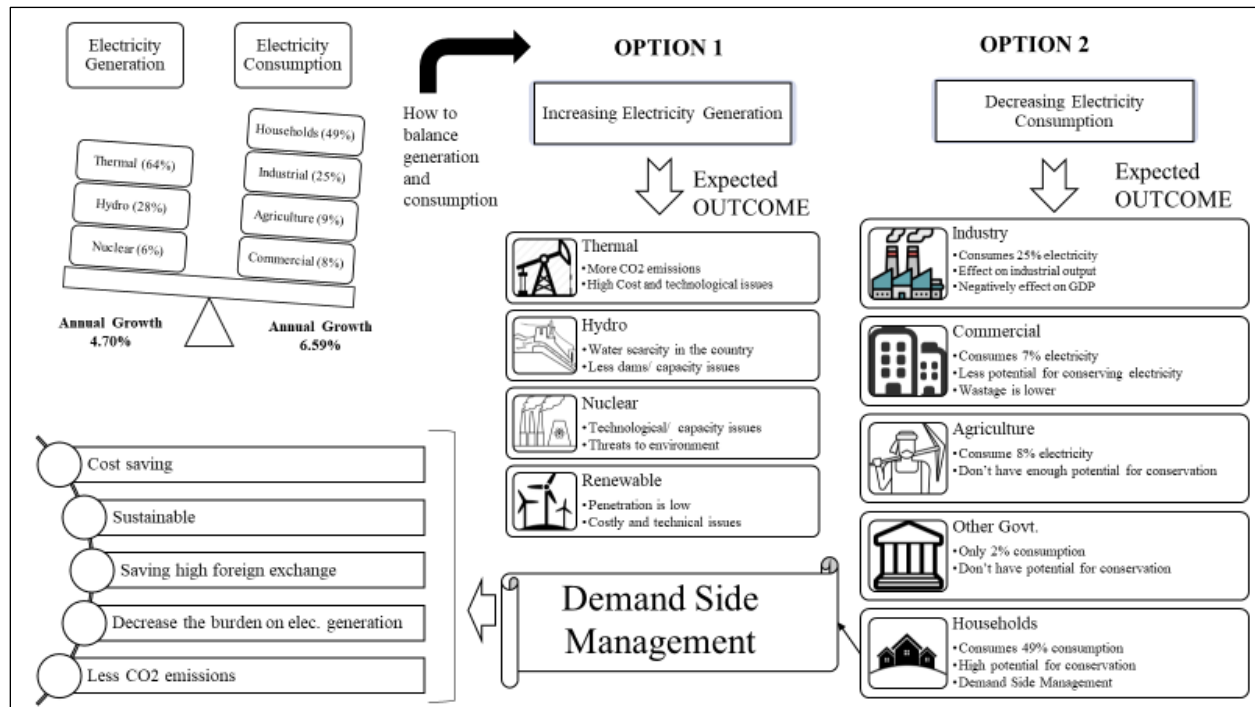

Figure 1. Flow Diagram of Different Options of Electricity Management

the largest proportion of electricity in Pakistan. Many previous studies explored the high energy waste by residential sector of different countries. Therefore, a great potential for energy saving lies with the household sector. Electricity consumption of households can be reduced through changing behaviour of people which can greatly impact on the total electricity consumption in the country. Secondly, monthly electricity consumption is sketched against different socioeconomic, building and demographic factors. This comparison will help to understand the electricity consumption pattern in different months and different people. Thirdly, appliance information and electricity consumption are also studied to check the effect of the specific appliances on electricity consumption.

MATERIALS AND METHODS

Toba Tek Singh district is ranked at 12th highest Human Development Index in Pakistan. It comprises upon four towns i.e., Toba Tek Singh, Kamalia, Gojra and Pir Mehal. The current study is conducted in Toba Tek Singh town (TTS). Total 133 households were interviewed. A random sample technique was used in the current study. List of electrified households at TTS is taken from Faisalabad Electric Supply Company (FESCO). Data is collected through a well-structured questionnaire which contains questions related to socioeconomic conditions, dwelling information, different appliances ownership, electricity conservation and awareness. Questionnaire also contains information about electricity connection through which the electricity bill of later months can be sought. After data collection, t-test is applied (Cecchini, 2021). Consumption of electricity of households are also compared by their different characteristics like income, age, education and occupation of household head. House information and appliance ownership

are also taken into account during comparing the household's electricity consumption.

RESULTS

Data contains 69.3 percent respondents from urban areas and 30.7 percent respondents from rural areas of TTS. The households come under different electricity feeders like Civil line (42.7 percent), Waryam (13.3 percent) and other feeders (44.0 percent). Data is collected in October, 2018 and updated in October, 2020. The electricity expenditure of each household is compared in the month of October for three consecutive years i.e., 2018, 2019 and 2020. Frequency distribution of variable is present in Appendix.

Results of t-test are presented in Table 1. It has been analyzed that electricity consumption expenditure has been increasing from 2018 to 2019 to 2020. This is due to use of more and more electric appliances in daily life of households. T-test results showed that income of households and electricity expenditures are correlated with each. Similarly, expenditures on electricity in 2018 and 2019 are also correlated with each other.

Figure 2 summarizes the electricity consumption in kWh by socio-economic and dwelling characteristics. Electricity expenditures from September 2019 to September 2020 were drawn against socio-economic and dwelling factors. A significant difference between electric consumption (EC) in rural and urban areas was observed. In simple words, from September 2019 to Feb., 2020 there found a downward trend in energy usage, which may be due to the winter season. After that we can see there has seen an upward flow in EC till September 2020.

Similarly, this study has also observed the EC by the household head. This factor is categorized as below 30 years (blue line), above 30 to 60 years (red line), and above 60

Table 1. Results of t-test

Variable	Mean	Pearson correlation	df	t Stat	P	t Critical	Decision
Monthly income	38457	0.676	132	10.92	0.000	1.656	Reject
Monthly electricity expenditures, 2018	4427						
Monthly electricity expenditures, 2018	5527	0.662	74	7.65	0.000	1.666	Reject
Monthly electricity expenditures, 2019	360						
Monthly electricity expenditures, 2018	5527	0.498	74	7.62	0.000	1.666	Reject
Monthly electricity expenditures, 2020	321						
Monthly electricity expenditures, 2019	360	0.818	74	2.30	0.012	1.666	Reject
Monthly electricity expenditures, 2020	321						

years. The overall trend of energy consumption (Sep 2019 – July 2020) was greater for the age of 31-60, while for two months found high for those who have age more than 60 years. Moreover, the electricity consumption was found very heterogeneous for illiterate, matrix, and graduate people. As given in the following figure there are 6 main consumers of EC i.e. government employ, private employ, businessman, self-employed, prisoners and other. As the income source is the main factor behind the consumption of goods, due to purchasing power. Data of households having income below 50,000, from 50,000 to 100,000, from 100,000 to 200,000 and above 200,000 was collected. As we can see in September 2019 there was high electricity demand from those who have an income of more than 200k, while it eventually decreases as winter started. From June to September 2020 there has seen a tradeoff between high-income consumers.

Overall electricity consumption increased in domestic economy for house size has increased from May to August. Likewise, the number of trees can significantly reduce the energy demand (EC). Therefore, those households which have not a single tree consumed more electricity as compared with others. In-floor construction there are different patterns such as mud, bricks, cement, and marble. In this, the electricity demand is high for marble floors. Roof construction also has a significant contribution to electricity consumption, to check the ratio of EC in roof construction this study has covered mud, wood and bricks, and cement. In the last, the material used for wall construction is measured by mud and brick cement. The electricity consumption in the usage of bricks-cement is high rather than mud.

Figure 3 presented the electricity consumption by appliances. More EC was analyzed for those households which have four bulbs at home. In the current era, rational consumers try to use some alternative light source rather than bulb and tube lights. To meet this need energy saver is used as the best alternative light source. The energy demand cause to increase as the number of energy savers increases, but the EC is high in the summer season as compared to winter. As the number of tube lights and led bulbs are increased, the electricity consumption is also increasing. The usage of fans and air coolers increased especially in summer season also cause to rise in electricity consumption over the time. But, there is limited use of EC in the winter season. The number of fridges also significantly increases the electricity demand. The up-surging trend in electricity consumption to its peak has been observed in summer, while winter has no much influence on EC. All the households which have 2 or 3 unit of fridges they demand the electricity according to their number of units. In this study, electric cattle and washing machines are measures with existence. According to the given diagrams, the electricity demand has increased for both appliances in the summer season rather than winter. Similarly, the usage of the oven in a household also raises the electricity demand.
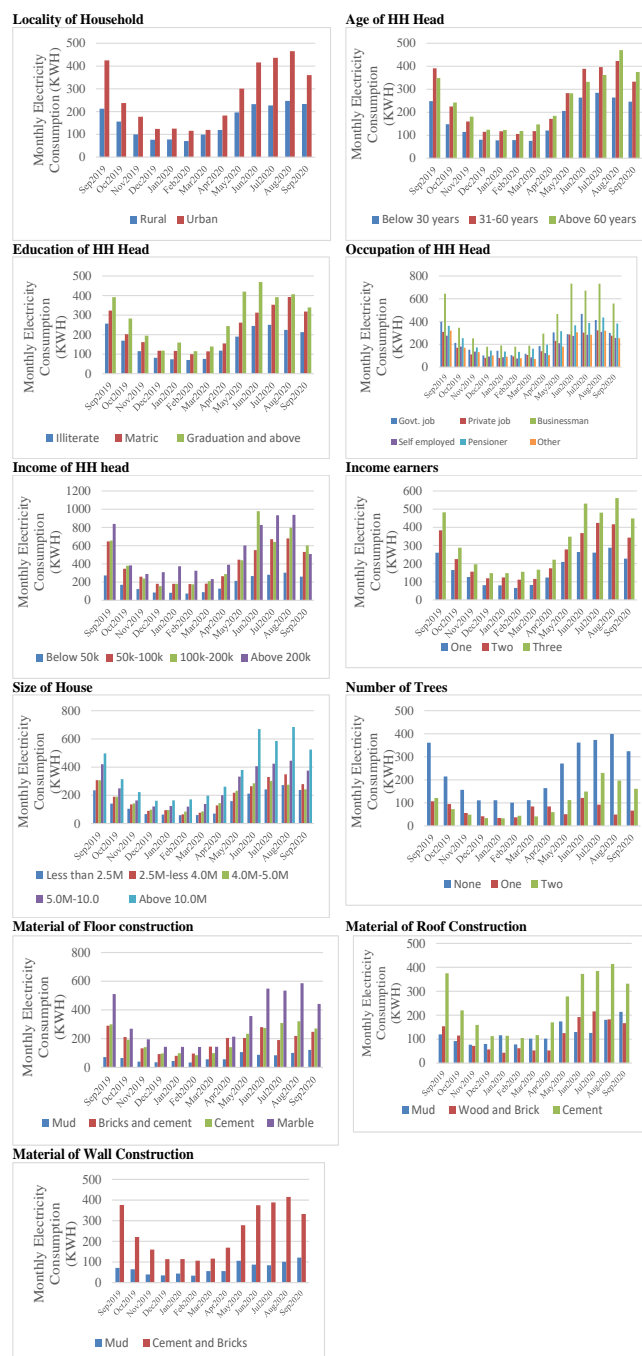

Figure 2. Electricity consumption (kwh) by different socioeconomic and dwelling characteristics.

There found an overall increasing trend in EC concerning the number of units, while in May 2020 the electricity demand by two units has increased. Electricity usage by iron also increased over time but it has an up-surging trend in the summer season, not in winter. In addition, the usage of TV, laptops, computer and printer increasing the usage of

electricity. In the case of TV, laptops, and computers the electricity use is based on the number of units. Thus, the number of units causes to rise in EC i.e. three units have more EC as compared to two and one. Likewise, a consumer has a printer or not, if someone has, due to this unit his electricity consumption is higher. UPS and generators are also used as the appliance of electricity consumption. All those consumers who have generator and UPS, they have more usage of electricity. This trend has been observed from September 2019-2020. Furthermore, water pumps can enhance the significant electricity demand, it is also dependent on the number of units. As the number of units increases the electricity demand also increases. But this demand has observed at a peak level in August. In the last, solar plates significantly rise in electricity consumption, and it has measured by none, one and two plates. That consumer who has two plates used more electricity rather than none and one. Similarly, in august 2020 there seen a high h electricity consumption for the domestic economy.
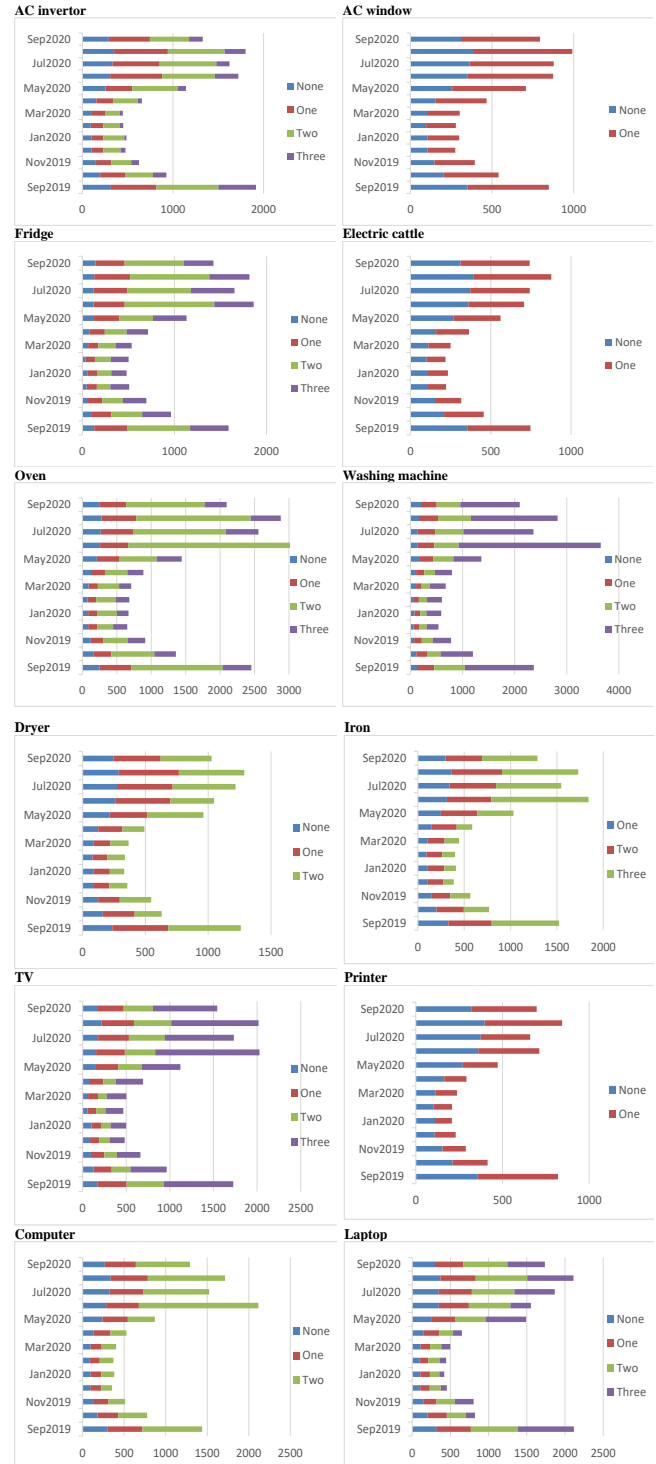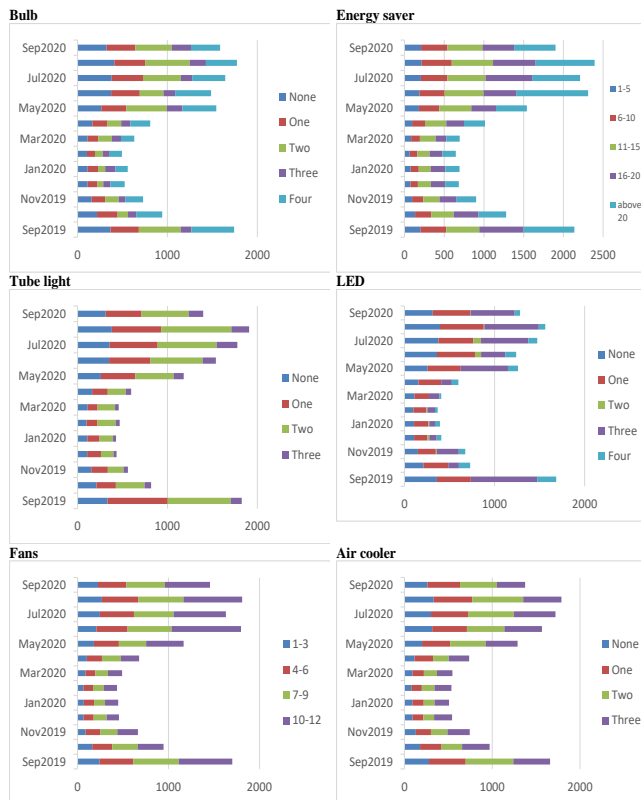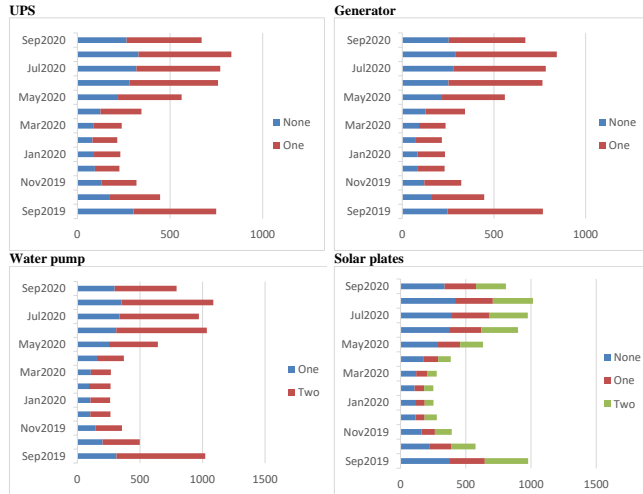
Figure 3. Electricity Consumption Pattern by Appliance Ownership

of energy consumption remained the same. This means that there is a need to keenly observe the behavior of people regarding energy consumption.
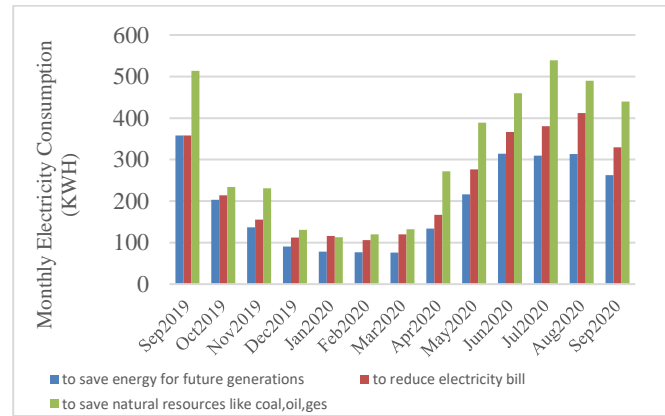

Figure 4. Electricity Consumption Pattern by Behaviour

Electricity consumption pattern is drawn in Figure 4. Households save energy due to one or other factors but pattern

APPENDIX
Table 1. Frequency Distribution of Variables

Variable	Description	Percent
Locality of households	Rural	30.7
	Urban	69.3
Age of HH head (years)	Below 30 years	18.7
	31-60 years	70.7
	Above 60 years	10.7
Education of HH head	Illiterate	22.7
	Matric	40.0
	Graduation and above	37.3
Occupation of HH head	Govt. job	8.0
	Private job	18.7
	Businessman	16.0
	Self-employed	44.0
	Pensioner	8.0
	Other	5.3
Income of HH	Below 50k	77.3
	50k-100k	13.3
	100k-200k	4.3
	Above 200k	4.0
Income earners in house	One	40.0
	Two	37.3
	Three	22.7
Size of house (marlas 272 sq ft)	Less than 2.5M	6.7
	2.5M-less 4.0M	10.7
	4.0M-5.0M	37.3
	5.0M-10.0	34.7
	Above 10.0M	10.7
Number of trees	None	93.3
	One	4.0
	Two	2.7
Material of floor construction	Mud	5.3

Variable	Description	Percent
	Bricks and cement	2.7
	Cement	34.7
	Marble	57.3
Material of roof construction	Mud	1.3
	Wood and Brick	5.3
	Cement	93.3
Material of wall construction	Mud	5.3
	Cement and Bricks	94.7

Table 4. Frequency Distribution of Households by Appliance

Appliance type/ name	Number of appliances	No. of households	Percentage of households
Lighting appliances			
Bulb	None	63	84.0
	One	7	9.3
	Two	2	2.7
	Three	1	1.3
	Four	2	2.7
Energy saver	1-5	21	28.0
	6-10	33	44.0
	11-15	8	10.7
	16-20	7	9.3
	Above 20	6	8.0
Tube light	None	68	90.7
	One	4	5.3
	Two	2	2.7
	Three	1	1.3
LED	None	63	84.0
	One	9	12.0
	Two	1	1.3
	Three	1	1.3
	Four	1	1.3
Cooling appliances			
Fans	1-3	15	20.0
	4-6	37	49.3
	7-9	17	22.7
	10-12	6	8.0
Air cooler	None	36	48.0
	One	33	44.0
	Two	5	6.7
	Three	1	1.3
AC inverter	None	59	78.7
	One	12	16.0
	Two	3	4.0
	Three	1	1.3
AC window	None	70	93.3
	One	5	6.7
Kitchen appliances			
Fridge	None	5	6.7
	One	65	86.7
	Two	4	5.3
	Three	1	1.3
Electric cattle	None	69	92.0
	One	6	8.0
Oven	None	40	53.3
	One	33	44.0

Appliance type/ name	Number of appliances	No. of households	Percentage of households
	Two	1	1.3
	Three	1	1.3
Laundry appliances			
Washing machine	None	2	2.7
	One	66	88.0
	Two	6	8.0
	Three	1	1.3
Dryer	None	32	42.7
	One	41	54.7
	Two	2	2.7
Iron	One	64	85.3
	Two	8	10.7
	Three	3	4.0
IT appliances			
TV	None	3	4.0
	One	58	77.3
	Two	11	14.7
	Three	3	4.0
Printer	None	73	97.3
	One	2	2.7
Computer	None	42	56.0
	One	31	41.3
	Two	2	2.7
Lamp	None	56	74.7
	One	17	22.7
	Two	1	1.3
	Three	1	1.3
Other appliances			
Water pump	One	66	88.0
	Two	9	12.0
Alternate energy appliances			
Generator	None	44	58.7
	One	31	41.3
UPS	None	45	60.0
	One	30	40.0
Solar plates	None	63	84.0
	One	7	9.3
	Two	5	6.7

Table 5. Frequency Distribution of Households by Behaviour .

Behaviour of households	Question/index	No. of households	Percentage of households
Save energy because	For future generation	63	84.0
	To reduce electricity bill	1	1.3
	To save natural resources like coal, oil and natural gas	11	14.7
Behaviour index	</= 15	1	1.3
	16-20	8	10.7
	21-25	33	44.0
	26-30	16	21.3
	31-35	15	20.0
	36-40	2	2.7
Awareness index	</= 15	9	12.0
	16-20	38	50.7
	21-25	24	32.0
	26-30	4	5.3

DISCUSSION

Electricity consumption in households in Pakistan remained at peak during months from June to August every year. It depends upon number of socio economic, demographic, appliance related and other factors related to construction material of houses. Electricity expenses of households are high in urban areas due to frequent use of appliances. These appliances for cooking, washing, heating, cooling etc. had not been used so frequently in past. It is also evident from analysis that households having trees inside or outside their house consume less electricity as compared to them who are lacking tree. The analysis of energy behavior showed that people think about conserving electricity, but they are unaware how to curtail their electricity bills. Usually, they also unknown about cost of electricity and time of high cost during a day.

Conclusion: The above analysis defines a clear path of conserving electricity by changing behavior of people regarding use of appliances through awareness sessions and publicity regarding energy demand management and planting trees. Resultantly, increasing demand of electricity by household sector can be reduced and foreign exchange on import of oil can be saved.

Ethical statement: This article does not contain any studies with human participants or animal performed by any of the authors.

Availability of data and material: We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

Consent to participate: All authors are participating in this research study.

Consent for publication: All authors are agree to publish paper in Journal of Sustainable and Economic Development
Code Availability: Not applicable

Authors' contributions: N. Akhtar and designed, completed the experiments and prepared the draft. M. K. Naeem and S. Ali reviewed and finalized the draft.

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